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AN AFFORDABLE APPROACH TO EARLY CRUISE MISSILE DEFENSE

William C. McMillin
Lockheed Martin Vought Systems
Dallas, Texas

LTC P. O'Reilly
Patriot Project Office
Huntsville, Alabama

Abstract

The Patriot system upgrade being developed will result in the world's most capable medium range air defense system. It is designed to buy back battlespace lost to recent developments in the air breathing and tactical ballistic missile (TBM) threat. The upgrades also reflect lessons learned in Desert Storm in defending against TBMs in combat. Although driven by the TBM threat, the upgrades include responding to another lesson learned in Desert Storm - the effectiveness of cruise missiles against ground targets. In designing the anti-TBM (ATBM) upgrades, it became apparent that an effective anti-cruise missile (ACM) capability could be obtained at little additional cost. The features needed for ATBM - better acquisition and track performance, improved discrimination and identification capability, bigger footprint, better lethality - resulted in system improvements that provide significantly better capability against cruise missiles. This improved ACM capability was recognized early and the system upgrades were tailored to take advantage of this additional benefit. The Army Mountain Top Experiment further explored how to take advantage of this by demonstrating beyond line-of-sight engagement capability. The net result has been the development of an effective, affordable ACM capability as a by-product of the Patriot system ATBM upgrades.

The Patriot air defense system was designed to be the backbone of an air defense belt across central Europe. It was initially fielded in the mid-80s. In the late 80s an Anti-Tactical Missile (ATM) upgrade was developed to counter the emerging tactical ballistic missile threat. This upgrade was done in two steps. First, a ground radar upgrade (PAC-1) allowed the radar to perform surveillance at higher elevation angles. Then upgrades to the missile (PAC-2) improved its capability against the TBM target. The TBM threat designed against was assumed to be compatible with the Intermediate- range Nuclear Force (INF) Treaty which the U.S. and Soviet Union signed in 1987. This limited the TBM range to less than 500 kilometers, which defined the altitudes and velocities of the TBM payloads to some extent. The Patriot ATM development program was still underway when Iraq invaded Kuwait in August, 1989.

The Desert Shield, Desert Storm experience resulted in a new environment for the Patriot system. Operational fire units were airlifted from their familiar settings in Germany and the U. S. and positioned in Saudi Arabia and Israel. The PAC-2 missile production was accelerated and installed in the field, while training for U. S. and Israeli crews was conducted in the U. S. and on-site. Once Desert Storm started, further changes in software and training were required because the TBMs being countered were clearly from ranges greater than those covered by the INF treaty. The bottom line was that, after the extensive testing Patriot underwent during and after fielding, its only combat experience was in an out- of-area location against a threat that it

was not designed for. It was also clear that this is probably the way it is going to be from now on. Based on this experience, a major system upgrade was initiated.

When completed, the PAC-3 system will combine the capabilities of the PAC-2 and PAC-3 missiles resulting in the worlds most capable medium range air defense system. It is scheduled to be fielded in 1999. The upgrades are designed to buy back battlespace due to recent developments in the air breathing and TBM threat, and to incorporate lessons learned in Desert Storm.

The primary performance drivers in the PAC-3 upgrade are related to the emerging TBM threat. The objectives are to improve acquisition and track performance, obtain better discrimination and identification capability, get a bigger defended footprint, and improve lethality against all TBM payloads. There are other system improvements included in PAC-3, but these are the drivers. They are listed in Figure 1, along with the system modifications made to resolve them.

Because of the very high velocities of the incoming TBM threat, it was necessary to increase the ground radar acquisition range to allow more time for the intercept and to increase the size of the defended area footprint. The ground radar average power is being doubled by the addition of a dual traveling wave tube transmitter. A new exciter and a new pulse doppler processor are being added to improve stability and create waveforms necessary to enhance tracking and detecting cued targets and targets in ECM and clutter. A wideband receiver and digital signal processor upgrades are added to improve classification, discrimination, and identification of both TBM and non-TBM target complexes.

These radar upgrades are integrated with other communication and data recording changes to further improve the warfighting capability of the system. The Expanded Weapons Control Computer in the Engagement Control Station (ECS) was upgraded with a new CPU, VHSIC, and more memory.

The defended footprint of the system was significantly increased by the addition of a combined Communications Relay Unit and a Launcher Control Station which allows launchers to be located 10 to 30 kilometers from the ground radar and ECS. This gives the commander much more flexibility in positioning his forces to protect critical assets from TBM attack.

The hit-to-kill PAC-3 missile was selected to provide the required lethality against all TBM payloads. Figure 2 shows the key features of the missile. The accurate active seeker, agile and very responsive airframe, and high data processing rate result in a very high probability of a direct impact on the TBM payload. The missile flies out on inertial guidance after launch, and has an uplink/downlink to communicate with the ground radar, which provides inflight alignment updates and updates the missile on the target location if necessary after launch. Also shown in the figure is the low explosive Lethality Enhancer which is only used against non-TBM targets. The sequence of events for a TBM intercept is shown in Figure 3.

In addition to the TBM lessons learned in Desert Storm, there was another important lesson learned that was not lost on the rest of the world. That was the effectiveness of cruise missiles against ground targets. As the PAC-3 upgrades were planned, the effectiveness against the cruise missile threat was evaluated. It immediately became obvious that the system features being incorporated for the TBM threat would significantly enhance the system capability against cruise missiles. A review of the ATBM features previously shown in Figure 1 shows that the performance improvements are in most cases directly applicable to the ACM mission. The functional similarities between the two missions is evident when the sequence of events for the TBM mission (Figure 3) is compared with that for the ACM mission, as shown in Figure 4.

The increased power, stability, and flexibility provided by the ground radar modifications greatly improved the ability of the radar to acquire, track, and identify cruise missiles in a clutter and ECM environment. The uplink/downlink to the PAC-3 missile provide a means to update the target position to the missile in flight. The PAC-3 missile itself was designed to operate in rain, so the seeker phase noise had already been set low enough to accommodate acquiring and tracking a cruise missile in a ground clutter environment. In addition, the missile seeker had robust ECCM against threats expected during the timeframe of PAC-3 deployment, target profiling, and other features for the TBM and air breathing threats so there was little else to do except tailor the software to include certain unique cruise missile characteristics. A summary of the missile features which provide a robust capability against the cruise missile threat is shown in Figure 5.

A further example of the flexibility of the PAC-3 system to handle the cruise missile threat was demonstrated in the Army Mountain Top Experiment, which was completed earlier this year. Figure 6 shows the essential elements of this experiment. The Army objective was to demonstrate the principle that track data from an airborne sensor could be used by a ground based air defense system for engagement and acquisition of a low-altitude cruise missile which was beyond line-of-sight of the ground based system. A BQM-74 drone flying very low over water (beyond line-of-sight to the Patriot radar) was acquired and tracked by sensors located on a mountain at a Hawaiian test range. These data were sent to a Patriot testbed at the foot of the mountain. A PAC-3 Dem/Val missile seeker and associated missile electronics, including an uplink receiver, were installed in a captive carry mode on C-130 test aircraft which was simulating the missile flyout. Information on the drone location was uplinked to the seeker via the Patriot radar, and the seeker searched the designated area, acquiring and tracking the target. There were 18 successful captive carry runs, and the data generated was used in over 100 successful virtual target 6-DOF intercepts. Tests were also conducted against low flying F-16 aircraft, and multiple target, target profiling, and polarization data obtained in the sea clutter environment. The demonstrated ability of the PAC-3 system to use external data to engage cruise missiles which are beyond line-of-sight to the Patriot radar is a further example of the robust ACM capability of PAC-3.

The PAC-3 upgrades to the Patriot system are a high priority program for the U.S. and the administration, and will result in a very effective air and theater missile defense system. The program is on track to be fielded in 1999. The flight test program will support the validation of simulations of PAC-3 performance against both TBMs and cruise missiles. This includes a series of captive flight tests with the EMD missile seeker looking down in various cruise missile engagement scenarios. Similar tests were conducted on the Dem/Val missile seeker prior to and during the Mountain Top tests previously discussed.

To further support the affordability of this multi-mission system upgrade, several actions have been and are being taken to reduce development, acquisition, and ownership costs. For the PAC-3 missile segment, a summary of these actions is given in Figure 7. The net result is that Patriot, which is still the premier air defense system in the world, will also be the most modern, effective ATBM system fielded and will have an affordable, effective ACM capability well into the 21st century.

Primary Drivers For PAC-3 Upgrade

Objective	Implementation	Performance Improvement
• Improve Acquisition and Track Performance	• Add Dual Traveling Wave Tube (Doubles Average Power) • Add New Exciter • Add Hardware and Software for Pulse Doppler Signal Processing	• Improves Multifunction Capability, Improved Detection Range • Allows Flexible Surveillance Modes (Expanded Search Sector) • Improves Stability (Clutter Rejection) and Enables High PRF, High Energy Wave Forms Which Enhances Tracking and Intercepting Targets in Clutter • Allows Creation of Waveforms Necessary to Detect Cued Targets Which Improves Surveillance • Supports Classification Discrimination, and Identification Waveforms • Also Supports Expanded Defended Area
• Obtain Better Discrimination and Identification Capability	• Add Wideband Receiver and Digital Signal Processor • Add Commanders Tactical Terminal and Hybrid Receiver	• Improves Discrimination by Providing High Range Resolution Capability • Reduces Missile Waste by Minimizing Engagement of Debris and Penetration Aids • Allows Receipt of External Data From Outside Sources for Fused Multi-Sensor Tracks • Allows Input From Sources Beyond Patriot Coverage to Improve Survivability
• Bigger Defended Footprint	• Add Launcher Control Station and Software Modifications	• Remote Launcher Capability Expands Defended Area 30 + KM • Provides Greater Tactical Flexibility
• Improve Lethality Against All TBM Payloads	• Add PAC-3 Missile	• Increases Missile Accuracy, Lethality, Fire Unit Survivability • Supports Expanded Defended Area
• Improve Firepower	• PAC-3 Four Pack Is Similar in Size to PAC-3 Canister	• 4:1 Firepower Increase for Each Launcher Loaded With PAC-3 Missiles

Figure 1

PAC-3 Missile Design Features for Robust Anti-TBM Capability Provide Very Good Performance Against Air Breathing Threats

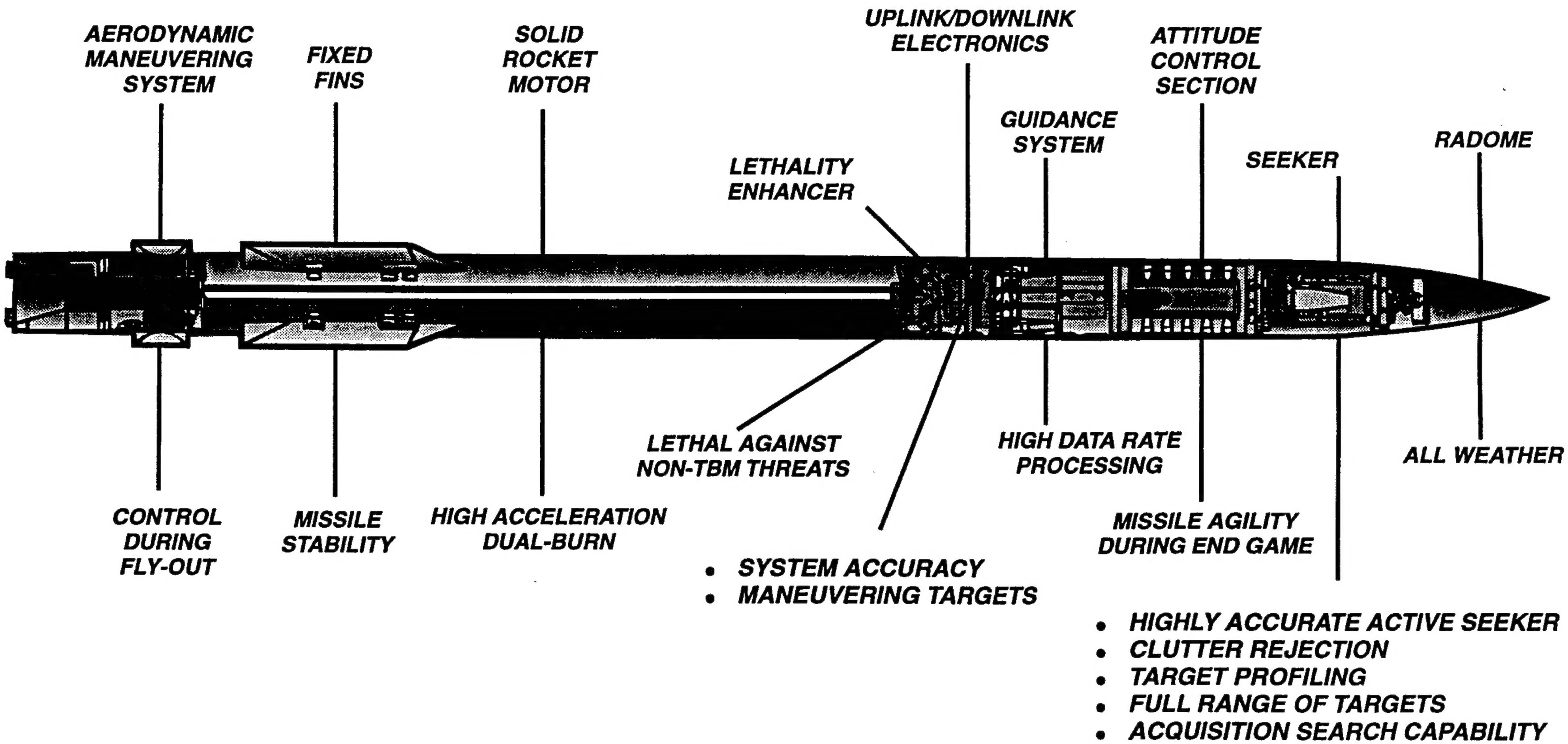

Figure 2

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Nominal PAC-3 System Engagement Timeline (TBM Target)

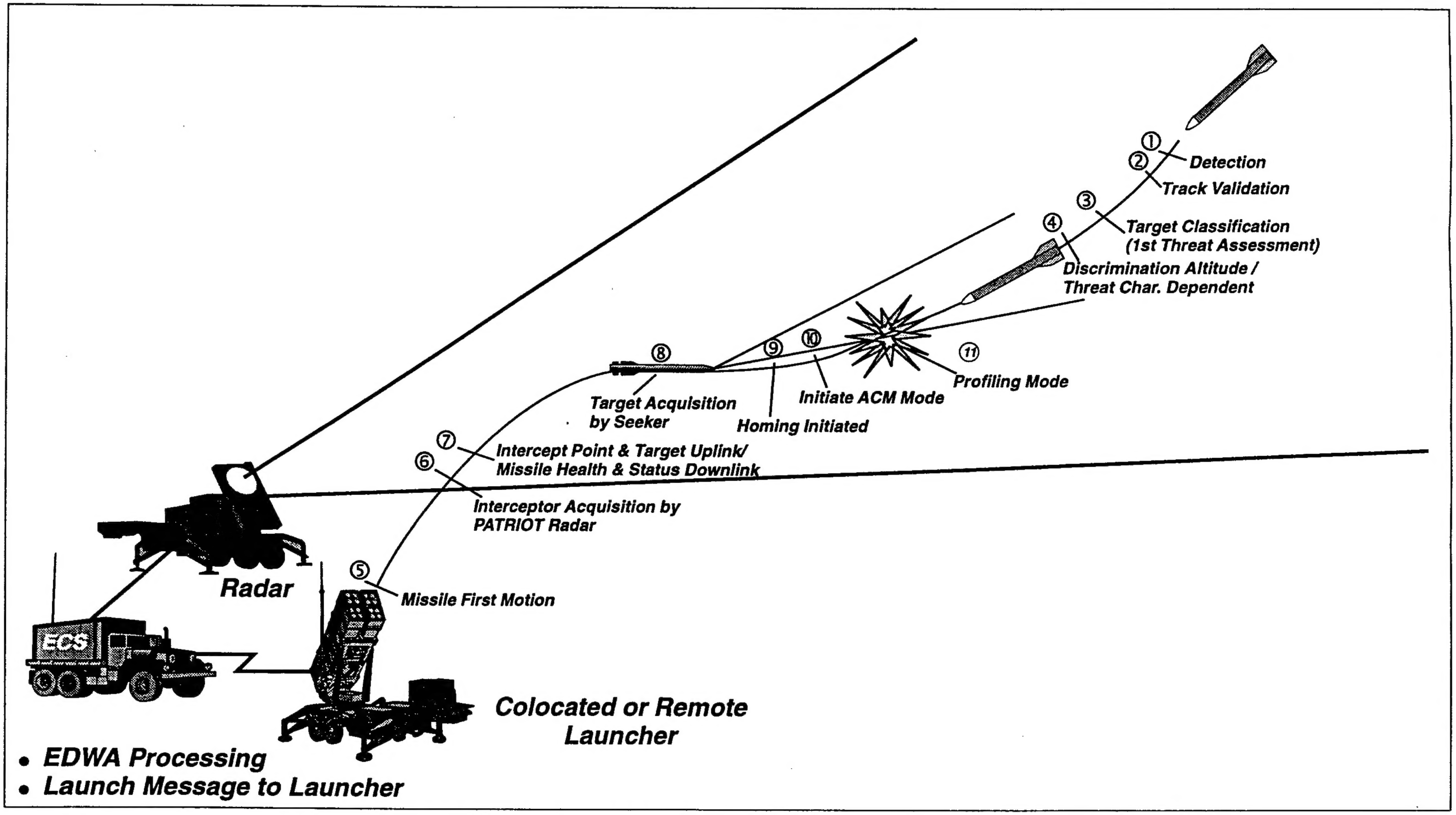

Figure 3

UNCLASSIFIED

Nominal PAC-3 System Engagement Timeline (Non-TBM Target)

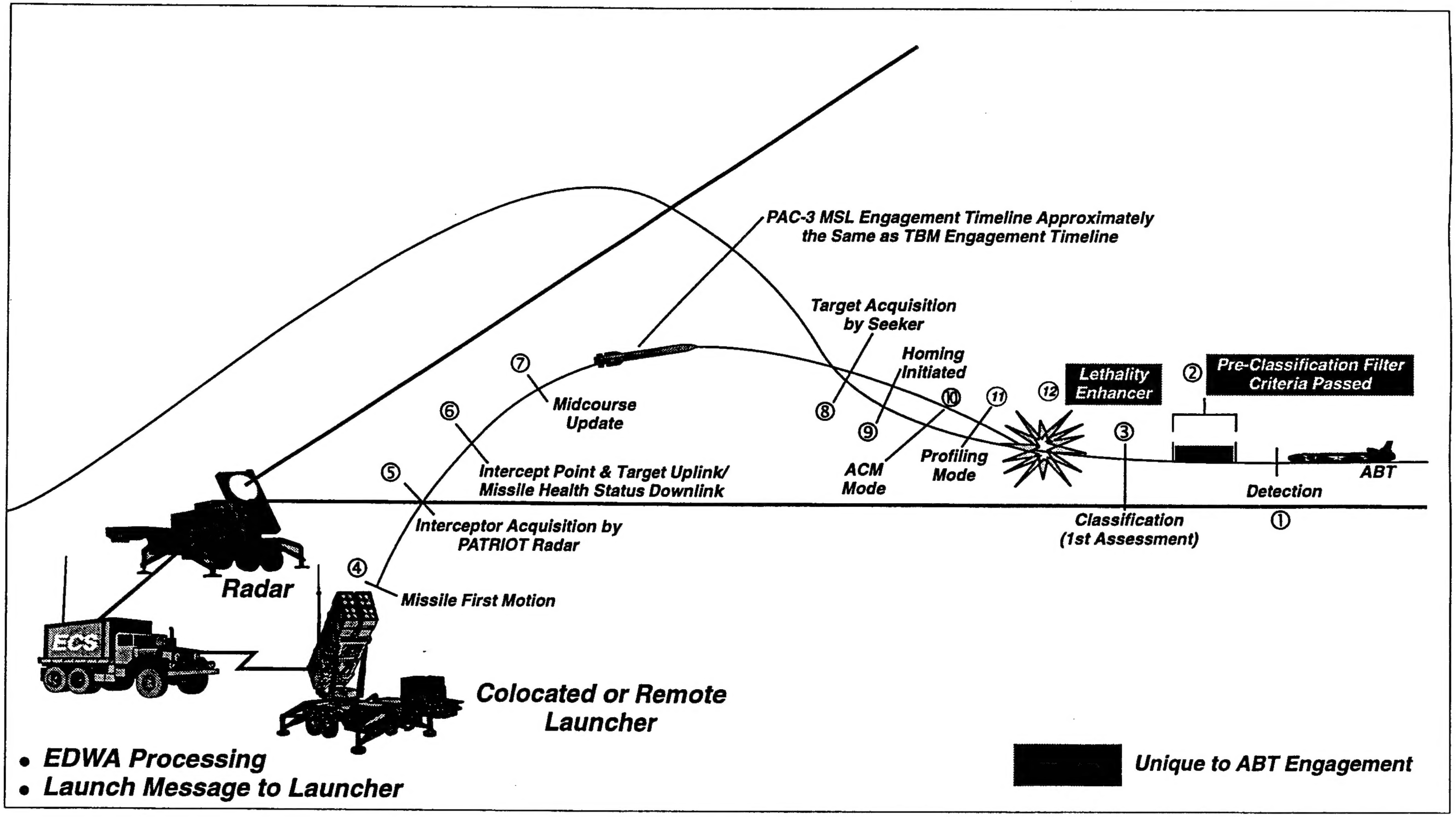

Figure 4

PAC-3 Missile Anti-Cruise Missile Features

Item	*Anti-Tactical Ballistic Missile Function*	*Anti-Cruise Missile Function*
Seeker		
• *Low Phase Noise in Master Frequency Generator*	• *Acquisition in Rain*	• *Acquisition in High Ground and Rain Clutter Background*
• *Active KA Band RF*	• *Highly Accurate Seeker Measurements for End Game Performance*	• *Same*
• *Large Dynamic Range*	• *ECCM*	• *ECCM*
• *Search Capability*	• *Acquisition of Low RCS Targets*	• *Acquisition of Low RCS Targets in Clutter and Multipath*
• *Target Profiling/High Range Resolution Processing*	• *Aim Point Selection*	• *Glint Reduction*
Attitude Control Motors		
• *Fast Response, Solid rocket Motors*	• *Agility in End Game, Small Miss Distance*	• *Same*
Uplink/Downlink		
• *Target Update Information*	• *Maneuvering Targets*	• *Maneuvering Targets; Engagement of Beyond-Line-of-Sight Targets*
• *Inflight Alignment*	• *Efficient Acquisition*	• *Same*
Lethality Enhancer		
• *Low Velocity Fragments*	• *Not Used Against TBMs, but Used Against all Air Breathing Threats*	• *Extended Battlespace Against Complex Shape, Extended, Soft Targets*

Figure 5

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Over the Horizon Testing / Simulation

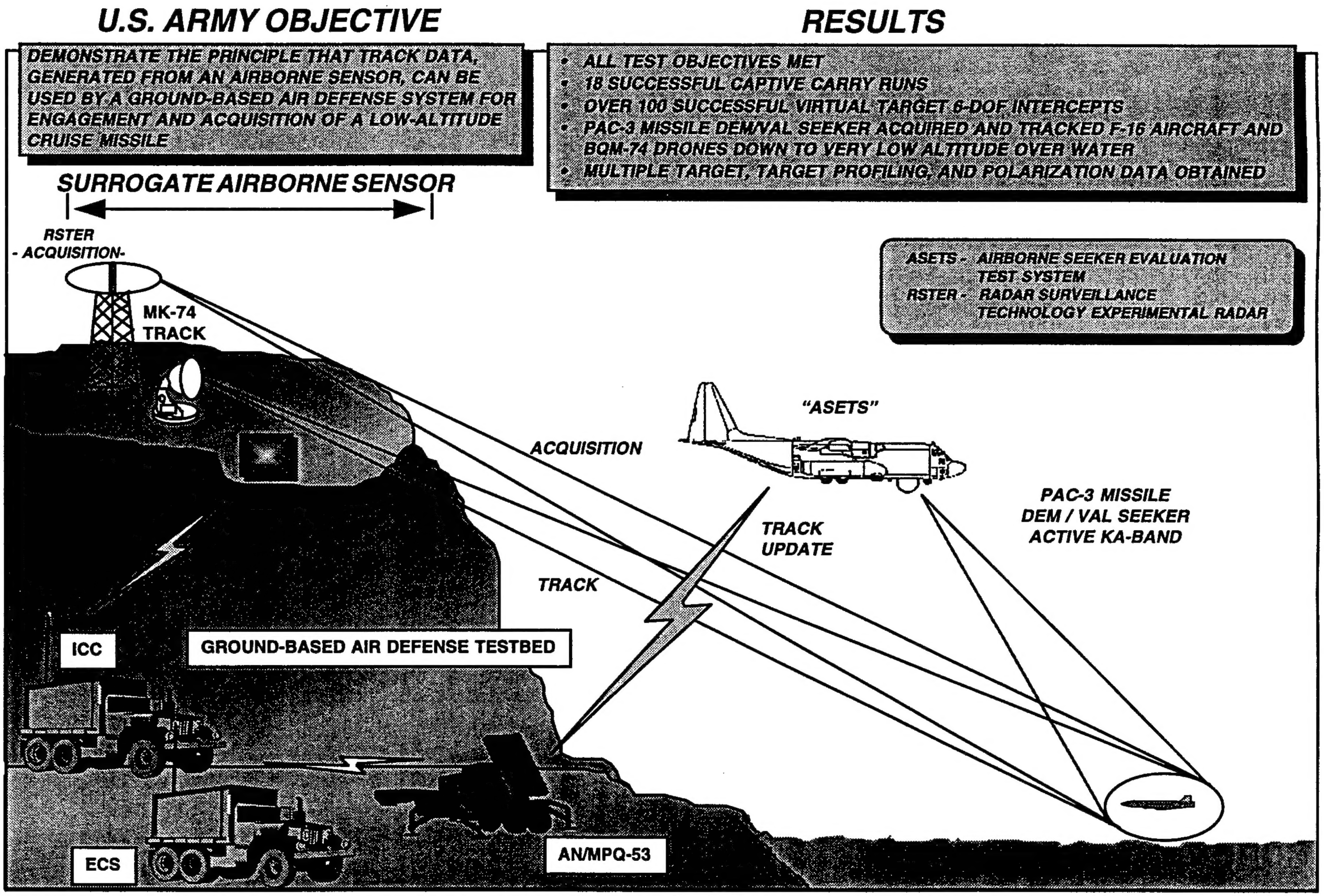

Figure 6

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PAC-3 Missile Segment Cost Reduction Measures

Item	*Cost Impact*
• *Streamlined Acquisition Process*	• *Reduced CDRLs, Meetings, Reviews* • *Allowed Use of Commercial Parts, Processes, Equipment* • *Tailored MIL Specs* • *Extensive Use of Simulations to Balance Testing*
• *Disciplined Integrated Product Team (IPT) Approach*	• *Enhanced Communications Between Contractor, Developer, User* • *Expedited, Better Informed Decision Making* • *IPT Training, Incentivization, Support Through All Contractor, Government Levels* • *Concurrent Engineering Inherent in IPT Approach*
• *Risk Management Approach*	• *Formal Risk Assessment / Risk Abatement Process* • *Develop Dual Sources for High Cost / High Risk Items* - *Attitude Control Motors* - *Radome* - *Traveling Wave Tube* - *Solid Rock Motor (SRM) Case*
• *Extensive Design-for-Producibility Trades*	• *Performance / Cost Trades, Including LCC* - *Master Frequency Generator* - *Seeker Transmitter (Wet vs Dry)* - *SRM Tooling Mandrels* - *Fixed Fins*
• *Optimize Use of Existing Government and Industry Facilities*	• *System Integration Testing Supported by Lockheed Martin Vought Systems, Raytheon and Government HWIL Facilities*

Figure 7